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MILITARY CHOLOGY

Chapter 6. UNDERGROUND MINE WARFARE

/Figures referred to herein are not reproduced but are available in the original document at the US Geological Survey.]

General and Historical

The first section, entitled "General Information Consuming Underground Warfare," defines the subject of underground mine varfare, distinguishes between attack and defense and stresses the necessity of assurate information of the area in which adderground mine varfare is conducted.

The rest section is entitled "Underground Mine Warfare in Past and Contemporary Wars." After mentioning a few examples of mine warfare in the 16th and 18th Conturies, it treats the defense of Seventopol as the classic example of underground mine warfare.

At Seventopol, the mine variance before Bestian Ro & was particularly instructive. Goological conditions there influenced greatly the course of the fighting, limiting both offensive and defensive plane.

From the longitudinal erose-section diagram of the Russian galleries shown in Figure 27 it is obvious that the eros is composed of heré, solid limestones, in which there were layers of clay at depths of 5 and 12.5 sectors. The first layer of solid clays (thickness 1.2 - 1.5 meters) permitted the installation of galleries without revolunt (diameters 0.9 by 6.75 meters). The walls were reinforced only in places and for short distances. All of the French and the greater part of the Russian mine galleries were laid at this level.

The galleries were often immisted with ground water, since the layer (sloy) of water-personals elege in the roof was exceled in many places or was so thin that it permitted the seepage of water. There was

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frequent crumbling in the walls and the ceiling, which seriously delayed work and in certain cases stopped it altogether. The clays of the second layer below were soft and plastic and required continuous bracing. The Russians constructed a number of countermines in this lower layer of clays. This gave assurance and raised the spirits of the garrison, since until then it feared being blown up from below.

During the entire seven-months period of mine variare, the Russians, not having any previously prepared countermines, constructed about 7,000 linear meters of galleries and sleeves (rukev), expending 12,000 kilograms of powder on 94 blasts, while the French constructed only 1,260 linear meters and expended 54,000 kilograms of powder on 136 blasts.

The peculiar nature of the Russian mine operations lay in their offensive tactics; the Russian counterwines not only hindered the progress of the attackers' underground operations but constantly pushed them back.

The experience of Sevastopol in commention with underground mine warfare was not taken into account by the command of the Czarist army, as was disclosed in World War I and even earlier at Port Arthur, where no countermine system was prepared beforehand, and where it was not possible to set one up when was krokeout, because of the lack of previously prepared cadres and the poor technical equipment of the army. The Czarist command tried to justify its inscrivity on the ground that the Japanese would not succeed in contracting mine galleries in rooky ground. And only when a Japanese gallery was within 30 meters of the foot of fort No 11, did the defenders begin to construct 1 mine gallery.

The war with the Japanese showed that underground mine operations can be conducted not only in an area of fortifications but also in field positions. It was waged at the time of the famous "Shakhe deadlock" on the Shakhe River, from November 1904 through February 1905, where Russian positions in some places were only 140 to 280 meters from the Japanese.

During the early phases of World War I both Russian and Germans made little use of underground mine warfare. But by the middle of 1915 a marked change had taken place in this respect. The text describes the intensive preparations for underground warfare and selects for extensive treatment the underground mine operations in the Messian spelling) sector in France.

In the Finnish campaign and on various fronts of World War II, the Red Arky slee found it necessary to use underground mine warfare.

Often it was necessary to undertake underground mine operations in order to cover up the approach of troops to the enemy's main line of resistance and to secure a jump-off position for awards and breakthrough of the fortified zone. One way of approaching the enemy under cover is by means of "sapy."

"Sapy" -- marrow, decy ditches -- were used in earlier wars in the siege of furtresses and strong points, approach to which was open to tactical observation of the defenders and was covered by fire. "Sapy" operations were widely used in the Sevastopol Campaign in 1855-1856, in the Japanese siege of Port Arthur in 1904-1905, and in many sectors of the fronts of the World War of 1914-1918. Often "sapy" were the only means permitting an approach to the enemy's fortifications for the purpose of destroying them or taking possession of them, insofar as there were no other means of breakthrough (heavy artillery, takks, sylation).

It was often necessary to have recourse to "sapy" work during the Finnish Campaign of 1939-1940 in the Excelian Arthens. "Sapy" found ruther wide use in various sectors of the front in the Great Fatherland War.







"Sapy" work can be carried on at a definite distance from the enemy; one cannot successfully advance closer to the enemy than 60-70 meters because of morter and grenade fire. Only underground mine galleries permit a close approach to the enemy's position. Sometimes that approach is effected by means of exploding a whole series of mine charges (garny) resulting in the formation of graters which are occupied by the attacking infantry. In order to continue the mine attack, new mine galleries are constructed from the bottom of the graters in the direction of the enemy's positions.

These methods of work, even when conducted under favorable geological conditions and in the absence of previously prepared enoug countermines, cannot be considered as the most desirable, since they consume a great deal of labor and time. However, in many cases, in the preparation of a bridge-head and in the approach to an especially important enemy objective, it is necessary to have recourse to mine work.

Thus, on the Bryansk front during World War II, our forces were unable to take a tactically very important height for a long time, in spite of intense artillery preparation and aerial bombing. The Germans beat off many attacks by our troops, inflicting serious losses on us, and only after the construction of three mine galleries and the explosion of charges was the height taken without excessive lesses.

In snother case, in attacking a carefully camouflaged enemy pillbox well adapted to the terrain and situated near our forward edge, it was impossible to use artillery or aviation because of the danger of striking our own forces. Approaches toward the pillbox were covered by intense enemy fire. The only suitable means of approaching and bloring the pillbox, therefore, proved to be underground mining operations. Mine galleries combined with "sapy" and trenshes permitted approaching the enemy with impunity and destroying the pillbox by exploding a powerful mine. As a result of the explosion a creater 22 meters in discreter and 8 meters deep was formed (See diagram and cross section of the approach to the pillbox in Figures 30 and 31).

In military operations conducted in large populated centers, mine galleries are used chiefly for the purpose of breaking down the fire system on the edges of the towns, since the area before the energ's forward edge is usually so well covered by fire that infantry often cannot follow the tanks. The most striking example of successful application of underground mine attacks in large cities is that of the fight of our troops at Stalingrad. Mine galleries, lying not very deep, permitted the uniormining and blowing up within 3 or 4 days of various buildings which had been transformed into centers of resistance.

During World War II especially wide use was made of the so-called "beneath-the-surface" (podpoverkinestmyy), 1.e., shallow-lying, mine galleries.

On one of the fronts of World War II, the following destruction of one of the enemy's centers of resistance was effected by means of underground mines. The Germans were very heavily furtified in the area of a city situated on the banks of a rather large river. The right-bank part of the city was occupied by our troops, but on the laft bank we occupied only a small part of the city's territory, and the Garman position wedged deep into our defense, occupying the bighest section which dominated the surrounding area.

Runerous ground attacks by our troops with air support failed, since the approach to this strongly fortified tone across open spaces was under good observation of the enemy and covered by his fire; all buildings were destroyed and wooden structures burnt. It was decided to construct a system of underground mine galleries to blow the German fortified centers of resistance.

As a result of engineering recommaissance consisting in the examination



of the walls of many hollows and craters of different sizes, with which nearly the whole place was pitted, the command was informed that crumbly sandy loan lay to a thickness of no less than it to 6 meters below the surface, that these layers contained a considerable number of boulders of various sizes and thin layers of gravel that the water-table level was 3.5-5 meters below the surface (doewneys poverkinost -- daylight surface).

The command had no information as to the kind of strate to be found below the sands or the depth at which these strate replaced one another; the engineering recommaistance had not taken into consideration the available geological data. The geological structure could have been easily ascertained from special maps available and from the excess-section of a prospecting pit sunk earlier in this region to a depth of 27 meters, and also by studying the exposed strate in the aloping banks of the river.

From the cross-section of the prospecting pit and from the exposed strata it was possible to detect that the sands were quickly replaced by dry, moralnic, clayer soil containing a small number of boulders. The thickness of these clayer soils varied on the average from 5 to 6 meters and only in places diminished to 3.0 - 3.5 meters. Still lower, i.e., under the clayer soils, lay the water-carrying, fine-grained sands of considerable thickness. (Their bottom was not established in the nearby exposed strata).

With limited information at its disposed the command gave orders to build underground galfories in the sands above the level of the water-table. Since the depth of the water table was not great, and accurate data on the relief was not available, it did not seem possible to set any figure for the protective thickness for the ceiling Tand follow it consistently. It was decided to lay the galleries by following the water table, thereby predicting the denger of piercing through to the day light surface. [Overhead covers (blindazh) were created, which were used for storing instruments, and from which the digging started at a depth of 2.5 to 3 meters.]

In spite of equinious reinforcini, cave-ins began to occur in the first 10 meters, the number of magnitude of which increased in proportion as the stope was removed from the entrance, since in approaching shell craters the sands would drumble at the elightest shaking. Aside from the great expenditure of time the extra work of fighting cave-ins (up to 69 - 70 percent of all working time was spent in reinforcing), the cutting of the galleries was great; impeded by frequent large bouldars which had to be by-passed, and in consequence of which the galleries sometimes diverged from the planned direction by several meters.

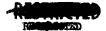
Among other difficulties encountered was that of disguising the noise of excevation work carried on at close range to enemy defenses.

In order to disguise the work of underground cutting and reinforcing, the operations were often carried on at night and accompanied by heavy rifle, machine-gun and morest fire. The dalays which resulted from this made it impossible to complete the work in time. When the Germans took the offensive it become necessary to abandon the exessential work, which was resumed only in the winter.

It turned out that under the soil conditions described above, digging of "beneath-the-surface" galleries in winter was incomparably more effective, since the frozen top layer of sell served as protection against cave-ins and made it unnecessary to reinforce the walls everywhere. Excavation work greatly increased, and the mine galleries were completed.

Underground Mine Installations and Charges

Underground structures built for waging nine warfare, which is simed at the reduction of enemy fortifications, the destruction of his personnel,



and repulsing mine attacks by means of underground explosions, bear the pure "mine structures."

Every mine structure consists of:

- 1. Entrances for communication with the daylight surface.
- 2. Collegies for advantament to the targets of mine attacks.
- 3. Sleeves (ruky) -- galleries of smaller cross-section, out either as the continuation of the main galleries or in a lateral direction to protect the flanks, and to become ventilation, water supply, etc.
- 4. Chambers -- excevations in a dead-and section of a gallery for placing explosive charges.
- 5. Perforated tubes (burovyye truby): combat tubes to hold explosive charges; listening tubes to listen to the mine operations of the enemy; and many others, for ventilation, water supply, drainage, etc.
 - 6. Combat wells -- at the bottom of which explosives are placed.

Mine thirances are vertical (mine-shaft type), inclined (mine-alope type) and harizontal (tunnel type). The most convenient entrances are those of the tunnel type, which are used only in steep alopes (steeper than 30 degrees). They are sloped at 0.09-0.05 to allow for water drainage. Eloped type entrances are usually constructed with a clope of 60 degrees in rocky or semi-rocky strata, of 45 degrees in clayer strata and up to 30 degrees in sandy or gravelly strata. Mine-shaft-type entrances are constructed in horizontal areas and most often it water-bearing and unstable strata. In digging through water-bearing layers (Sloy) and quicksands, timber pilings in the shape of grooved boxes are used, out of which the stratum is dug and the water 10 pumped. Constructe collars (kal'tso) and other rethods of digging are used.

Entrances are sometimes round but more often restangular, with arcss sections of 0.9 x 0.9 meter; I x 1 meter; 1.2 x 1.2 meters; 1.5 x 1.5 meters and larger.

Mine entrances are situated in shaltered, well-expendinged places on reverse alopes, for example, and against the direction of prevailing wirds. They are speed at intervals no closer than 20 - 25 meters, to prevent destruction or caving in from bursts of large-caliber shells and aerial bombs. It is not advisable to locate entrances in helious or degreesions, where poison gas may stend too long, or in sectors where surface water in the rainy season or the malting of snow or subsoil waters may flood them.

In lowlands where either the sloped-type or shaft-type entrances are used, a protective layer of veter-impermeable strata (porbin) about 2 meters thick should be left untotabled. In order to prevent access of surface waters into a sloped entrance, a water-collecting well is dug in front or inside the entrance. If geological conditions permit, the unter-collecting wells should go down to the water-absorbing layers (aloy). However, construction of such water-absorbing wells is in many cases impossible, since the waters from them might gain access to the mine gallery, as is shown in Figure 32.

Mine gallwise are either horizontal or sloping (descending or rising). Their dimensions are : 1 meter (high) ± 0.75 meters (wide); 1.2 ± 0.9 ; 1.3 ± 0.9 ; 1.5 ± 1.2 ; 1.2 ± 1.35 ; and up to 2 ± 1.8 meters.

A mine charter with a previously prepared explosive thangs is called a mine. Mines of the defender, in contrast to the mines of the attacker, are called counterwines. Depending upon the nature of their effective action, mines are divided into outer (nearly) or underground action. The former





produce craters in the earth's curfact with a circular embenkment or create a bulge and are called bulging mines (vypirayushchiye miny). The latter, called esmouflats, do not break the surface of the ground.

Upon explosion of an enter-action mine a crater is formed with depth "p." The distance from the center of the charge to the surface level of which the activity of the explosion is sized is called the "line of least resistance" (INS) and is designated by "h." The radius of the trater is designated by "h" and is measured on the earth's surface. The relation of the orator's radius, "r," to the line of least resistance, "h," is I and is designated by "n." With reference to "h," mines are classified into sormal (n = 1; r = h), amplified (n > 1, r > h), and reduced $(n \neq 1, r \leq h)$.

Bulging mines and the largest types of camouflets are used mostly as reduced mines.

Norsal and amplified mines are used to form craters in mine warfare, to destroy enemy fortifications, to describe enemy countermine systems, to build trumches and communication trumches, to blow passages through wire entanglements, etc. Bulging mines and the largest camcuflets are used by the defense to blow the mine system of the attacker, to destroy reinforced communication points, etc.

As regards their relative positions, mines are either eingle (their craters on areas of demalition do not intersect each other), adjacent (their craters or demolition areas touch or intersect each other), or in tiers (with charges placed at various toyths).

Computation of the size of the charge of mines is done by a specialist in blasting work — a mine expect (miner). But the military geologist can render him great aid by indicating the peculiarities of the geological structure and the hydrogeological conditions of the wros, since the size of the charge and the effect of the explosion are determined in a great measure by the character of the strate and their stratification.

Charges of single mines are computed ascording to the formulas

$$0 = 10^3 (0.1 \div 0.6n^3)$$

where C is the charge in kilograms;

K is the coefficient, varying with the strate and the explosive material.

h is the line of least registance in meters.

n is the index of the mine's action (s = \frac{r}{h})

The value of K is taken from Table 10 (see below). However, that coefficient is best selected by the miner in consultation with the military geologist, since it depends upon the contents and nature of the strate.

The weight of a bulging mine charge is equal to 0.4 Itwo fifths of the charge of normal mine); the weight of the biggest canculate mine charge is 0.2 (one fifth of the normal charge).

When confronted by betarogramous strata consultation with the military geologist is especially urgand. When the strata are more or less parallel to the exploded (horizontal) surface (Figure 34) the charge of the mice is determined by the sum of charges required for each layer separately, in accordance with the following fermile:

$$C = /\frac{\pi}{2} (h_2^2 - h_3^2) + \frac{\pi}{2} (h_2^2 - h_3^2) + \frac{\pi}{2} (0.4 + 0.6 h_3^2)$$





where h, h, h, are the distances from the center of the charge to the cuter surface of the corresponding layers;

and K, K1, K2 are the corresponding values of the coefficients of the strate and the explosives.

When a gallery is blasted, the greatest distance from the center of the mins to the gallery is called the radius of destruction. A distinction is made between the horizontal radius of destruction $(R_{\rm p})$, which is a horizontal (large) scalaris of the ellipsoid of destruction, and the vertical radius of destruction $(R_{\rm p})$, which is the vertical (small) scalaris of the ellipsoid.

The shortest distance from the center of the mine at which the gallery is not destroyed is called the radius of safety (of concussion /sotryascalys/). The horizontal radius of safety (S_p) is the horizontal (large) semisaris of the collipsoid of safety; the vertical radius of safety (S_p) is the vertical (small) seriaxis of this ellipsoid.

In computing the radii of destruction and safety, the following formulae are used:

Vertical radius of destruction:

$$R_{v} = mh \sqrt[3]{0.4 + 0.6 \text{ n}^3}$$
 (amplified wine, $n = 1-3$);

 $R_v = mh$ (normal mine, n = 1);

 $R_{\rm y} = 0.7$ mh (bulging mine, n = 0.6-0.7);

Re = 0.57 mh (largest camouflet, n = 0.5-0.6).

In these formulas "m" is the coefficient which varies with the strata (fir sands, - 1.5; for clays, - 1.36 to 1.43; for rocky strata, - 1.0 to 1.2). The other symbols were explained above.

If the vertical radius of destruction $R_{\rm g}$ is taken as equal to 1, then the horizontal radius of destruction $R_{\rm g}$ = 1.4 $R_{\rm g}$, the vertical radius of safety $S_{\rm g}$ = 1.75 $R_{\rm g}$ and the horizontal radius of safety $S_{\rm g}$ = 1.75 $R_{\rm g}$.

A mine attack in most cases begins with the construction, in the rece of fire positions, of a mine trench, in which are found entrances to the galleries for the offensive. Entrances to mine galleries can be constructed immediately from the surface only under favorable relief and camouflage conditions, generally on steep reverse slopes.

The number of offensive galleries is determined by the tactical problem, the available time, technical means and geological conditions of the arcs.

Table 10. Values of Scoffingent K for Various Strata and Soils

This table gives data for amounts and TMT. Explosives of reduced strongth should be compared to smannite, and of normal strength to TMT. When risource are present, the values of K may be divided by 1.5 or 2.

Strata and Materials	ĸ		
	Amon1to	THE	
Newly filled-in, orumbly, humas soil	0.5	0.43	
Serdy, homes soil	0.95	0.82	
Solid, clayer, hungs stil	1.10	0.95	
Hamis soil with gravel	.98	.85	
Solid, pure send	1.20	1.03	
Wet sand	1.27	1.10	
Sandy Loan	1.29	1.11	
Russis soil mixed with stone	1.36	1.17	

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Table 10 (Contd)

Strata and Materials	and the property of the property of the second	A CONTRACTOR OF THE PARTY OF TH
	Anthonite	THE
Solid clay and clayey soil	1.37	1.18
Chery or sendy loan stony	1.50	1.29
Clay with boulders	1.64	1.41
Sand with gravel and boulders	1.65	1.42
Very solid clay	1.90	1.64
Limestone without fissures	2.15	1.87
Granite and gnoiss	2.58	2,26
Masonry of natural stone	1.06-2.32	0.94-2.45
Congrete	3,59	3.12

Figure 35 is a diagram of the disposition of three mine galleries in an attack on a fortified area of the enemy. The galleries must not be situated so close together that the enemy could destroy two adjacent galleries with one blast. The distance between the galleries should be no less than 2.3 of the line of least resistance. For protection against enemy attack, branch galleries, called "siseves," are constructed from the outer galleries. Sloeves are put out from other galleries only when the latter are widely separated and are few in number.

Two-story gallaries are sometimes constructed. The purpose of the upper gallary is to divert the enemy's attention from the basic operation in the lower story, to provoke the explosion of his charges prematurely, and to destroy his countermine system. The minimum vertical separation must not be less than the radius of the sphere of destruction from the explosion of the darge of the upper story.

In mine defense the same types of underground mining are used. In highly fortified areas, countermine systems are constructed beforehand, most often of concrete, reinforced-concrete, or artallic jacketing. When a mine attack is anticipated the countermine system is developed and extended.

Ranio Tables and Technical Requirements of Geology and Hydrogeology

In the erection of mine attructures a great many demands are made upon the geologist. Chief among there are the following:

- L. Mine excevations should be undertaken in strate which are easiest to work and jet sufficiently stable and impervious to gas.
- 2. Core should be taken that mine constructions are not flooded by subsoil waters.
- 3. All mine structures, with the exception of the so-called "beneath-the-surface" [type], must have in their roufs a thickness of the protective layer (tollahous) which affords adequate protection against anticipated weapons of attack.
- 4. Mine structures must not be exected in filled-in alopes or in alopes entangered by landalide, cave-in or other physicognological phenomena.
- 5. Stresses the need of proper concealment and camouflage during excevations. \mathcal{T}
- 6. Nine calleries must be dug in geological strute which would create the greatest difficulty for the mine work of the energy (the strata below the bottom of the calleries should be of a kind that is difficult to work of waterbearing — containing pressure waters, etc.)
 - 7. Mine work must be protected by appropriate underground recommaissance



_ 8 _

aiming at the detection of the enemy's underground work, as well as obtaining necessary geological information for the construction of one's own mine galleries and enemy countermines.

The success of underground mine work depends in varying degrees upon a number of natural factors, chief smong which are subsoil waters, the composition of strata and the conditions of their cocurrence.

The section entitled "The Role of Surface and Subsoil Waters" reiterates the difficulties resulting from subsoil waters in underground mine construction and lays down rules to overcome these difficulties. Entrances and galleries should not be dug in water-bearing strata. If however, this cannot be fully avoided, care should be taken that a water-impervious layer is left in the ceiling of the gallery. Similarly a protective layer is to be secured when the gallery is above a water-bearing stratum. The thickness of the protective layer is to be determined by the formula h = B, where B is the amount of pressure in meters and Y is the volumetric weight of the layer between the floor and the water-bearing stratum. If "h" is less than B the gallery will be flooded.

The following section, entitled "The Properties of strate which contribute to the success of underground mine construction," lists such properties as the case of processing, resistance to drilling, stability of the walls and the ceiling,

Simulficence of the Conditions of Occurrence of Strate [poroda]

The conditions of occurrence of strata play an important part in underground mine variare. They often determine the tactics of vaging underground mine variare and the selection of levels (gorizont) for mine galleries which insure the quickest pessege and permit advantages over the enemy both in mine attacks and in beating off enemy counterattacks.

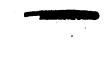
If the strate are horizontal and coordinated and their thickness is more or less similated, no difficulties are met in the selection of mine levels or in the working out of plans for mine attack.

These questions are worked out most simply in regions where the horizontally stratified original layers are ordered by a thir operat of quaternary deposits. Under such conditions the geologist can establish a geological cross section congrutatively easily, and the selection of the or several layers (plast) for the excavation of mine galleries can be made rapidly and unerringly.

Complications wrise in mine construction when the borders of the layers (plant) are uneven, especially if the formation of the original strate is deeply grooted by an ancient wash cut, levelled off, and unnoticed in the contemporary relief, in the layers (toleboha) of glacial deposits with frequent changes in the thickness of the layers (plant), in a zone of aligning strate (poroda), etc. To all these cases, a careful and detailed investigation of the geological execute of the area is required.

Even more complicated is the question of selecting mine levels and formulating plans for conducting mine variance in those areas where the strata are crumpled with folds, broken up with faults, notehed with veins, etc. In such conditions, as a result of the shift of strata of varying processability and variable conductivity of water it is necessary often to abendon the waging of underground mine werfere.

A sloping drop of layers (plast) on the side of the attacks: with a rise in the direction of the energy's position is fivorable for the exceptation of mine galaries, since this facilitates hamlege of the excepted material as well as drainege of the installation in case of water seepage. However, if





there is a sharp drop of layers, especially on the enemy's side, the success and expediency of waging underground mine warfare are doubtful.

When there is a broken cocurrence of strate it is difficult to forse the possible measures of the enemy. The stratification of layers also exerts a great influence on the conditions of sound camouflage, on overhearing the enemy's excavation work, on the size of the explosive charge, etc.

Stability of Strate in the Ceiling and Walls of Underground Installations

The cutting of strate in underground excavations causes a redistribution of stresses in the ceiling, which results in the caving-in of the roof, exfoliation, landslips and buckling of the cruspled strate, and shrinking and distortion of the constructions.

In order to protect the underground structures from deformation and to facilitate further work, reinforcements which absorb the stress are used. This atress of strats is called "mountain stress."

The amount and direction of the mountain stress depends upon the composition of the strata, their stratification, the degree of their decomposition, water saturation, the depths of location of the constructions, etc.

Cortain strate, such as stratified marl, after they are uncovered in the excevation, quickly change their firmness. Strate of this type are said to have "subsequent fragility." Fragments of such strate become detached from the coiling and walls of mine galleries and chambers.

The "subsequent fragility" of strate usually increases with greater fracturability and weathering of the strate, as well as with the increased dimensions of underground works.

Strata as Protective Layers

Underground excavations must be protected from above by layers of struct to withstand destruction by shells and aerial bombs. The thickness of the protective layer is determined on the one hand by the calfibre of the shells or aerial bombs and the obspaceter or dimensions of the construction, and on the other hand, by the composition of the structs and their vulnerability to shells and aerial bombs. Tables 7 and 8 /not reproduced/ give the values of protective layer thicknesses in relation to strate and the baliber of shells or bombs.

In the opinion of certain military engineers, field underground work can go on irrespective of the arch of stress; only the work of the inner bracing has to be taken into account, in which case the thickness of the protective layer diminishes.

As far as protection from bullets and fragments as concerned, it is quite sufficient to lawve a layer of stratum 0.7 meters thick over the ceiling. Shallow construction of the "beneath-the-surface" type are being ever more widely used at the present time, since aside from affording some protection from hits, they allow constition of numerous works (underground mining, underground communication trenches, etc.) concealed from the energy.

This method of mine work takes on especially great significance in tinter when the fresen ground has far greater redistance to persecution by bullets and fragments and at the same time supports the ceiling better without requiring breaks.

- 10 -



Size of Charge and Effect of Explosion on Properties of Strata and Conditions of Stratification

In underground mine operations the objective is to destroy, by means of explosions, only a definite part of berritory and, with cancuflets, only a definite zone of strata. Therefore, the question always arises as to how much explosive material it takes to attain the required result. If the charge is too small, the explosion does not reach its goal, and conversely, if the charge is too great the resulting explosion is so strong that the sectors and structures which ought to have been saved are also destroyed. The experience of underground mine warfare has taught that such disproportionately great explosions not only destroy the plans of mine warfare but also cause harm to one's own troops and fortifications. A good example of this was the inordinately large mine charges exploded by the Austrians in the Saint-Simon area on September 23, 1916, which inflicted great damage to the Austrian positions.

The size of the charge depends, on the one want, upon the type of explicative used and the depth at which the charge is placed and, on the other hand, upon the composition, the properties, and the conditions of the occurrence of strata above the place of the explosion.

It is known that massive rocks (skal'mays perces) when blasted behave differently from schistose strats, and that the effect of an explosion upon thick layers differs from that on thin ones. Explosive waves are best propagated longitudinally through rocky layers, and worst perpendicularly to the direction of stratification, particularly if the dense layers are alternated with weathered clayer deposits and other interstratifications. The effectiveness of an explosive charge will not be the same in layers lying horizontally with a slight tilt to the horizon as in steeply sloping layers.

Of great importance is the degree of destruction and the fissuration of a stratum. Cases have been observed when, in blasting energy mine galleries situated in rocky strata which were fairly similar in composition but dissimilar in degree of fissuration, the various blocks of massive rock did not so mich crumble away as dislodge and replace each other, with the result that the galleries only narrowed down and got out of alignment. In fissured sandatones, having thin clayey seems, heavy explasions were observed to cause these clayey seems. The mine galleries were not destroyed despite the fact that the walls were not braced.

In calculating the size of a charge under diverse geological conditions an accounting is taken of the composition of the strate, their solidity, occurrence, degree of scathering, of fiscuration, of water saturation, etc. Without this information the capper who is not sufficiently acquainted with the geological conditions is apt to make serious blunders. The advice of a military geologist can render him great and valuable sid.

The section entitled "Importance of Sound Conductivity of Strata" is devoted to general observations of the extent to which sound conduction depends on the type of wound most frequently occurring in underground works and the characteristics of strata through which sounds are transmitted. These observations are summarized in Table 11 which is supplemented by another table from an Itelian source.

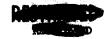


Table 11. Distances from which Sounds are Audible in Strate?

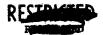
Nature of the Sound	Strata	Distance Without Instrument	in Matera With Seismo- atethbocops
Work with pickers	Chalk	45	90
	groth cyal	38 15	4 9 30
Work with shovel	Chalk	21.	37
en e	Clay Sendy clay	15	34 9
Walking on wooden floor	Chalk	15	2կ
	Clay Sondy clay	1 <u>0</u> 3	18 7.6
Falling soil	Chalk	11	18
2000 00 m	Clay Sundy clay	9	15 6.1
Surrendura analysis Adi annihib	Chalk	6	17
Dragging sacks of earth	Clay	4.6	10.5
* <u>A</u>	Sandy oldy	1.5	5.5
Conversations	Olaj	3.65 2	- 15 9 4.6
	Sandy clay	1.5	4.6

*Data teken from field namual for engineering troops, <u>Underground</u>
<u>Mine Operations and Mine Warfare</u>. (Podsesnowiwnyse reboty 1 minneya bor ba), 1942.

Table 12. Maximum Distances (in Maters) from which Various Sounds can be Marri in Various Strata*

	Rook		Soil	
Snears of the Scand	Ford	8of6	Bard.	Soft
1. W1	thout Inst	rumits		
Drilling	60-80	40-50	30-40	1-18
Breaking with shovels	20-25	15-20	10-80	2-5
Walking on wooden floor	12-25	1ĥ-16	10-15	
Falling waste or landslips	10-15	8-12	8-10	
Dragging of materials	10-25	5-15	4-3	1- 4
Ocaversations		3- 5	6- f	
2. With Aid of 8	el mast et!	roscobe et	d. Googha	0.0
Drilling	120-160	90-100	45-55	25-35
Breaking with shovels	40-60	30-40	30~40	
Walking on wooden floor	35-50	25-30	20-25	7-10
Falling waste or landslips	25-40	18-20	15-20	6-1 0
Drawing of unterials	20-40	15-25	10-15	5-10
Conversations	20-30		5- B	3- 5
3. With Ald	of Solan s	ria regiones)	

- 19 -



Pable 12 (Contd)

	Rook		Soil	
Nature of the Sound	Hard	Bort	Herrd.	Soft
Breaking with shovels	30-40	20-30	20-25	6-10
Walking on weeden floor	25-35	20-25	15-20	5- 7
Falling waste or landalips	15-25	14-16	10-15	4-6
Dregging of materials	15-30	10-20	6-10	3- 6
Conversations	10-60	10-25	3-6	2- 3

*Data taken from the Italian Manual for Mining and Blasting Operations, Fart II - Mine Works, 1937.

The section on "Ges Permeshility of Strate" stresses the importance of studying the capacity of various strate for retaining and absorbing poisonous gases. The greater the fissures, the easier gases can find their way into the galleries and underground thankers. The military geologist must supply the requisite information.

Another section deals with the role of the color of strata in camcuflaging underground works. The observations are of a general character. Strata may change their color with the progress of excevation in depth; brightly colored strata are hard to cancuflage; strata change their color when they dry out, etc. By knowing the color of the strata it is possible to establish the levels at which the enemy is digging his own underground galleries.

Military-Geological Servicing of Underground Mine Works

Military-geological servicing of underground mine works is of parametric mount importance. The diversity of geological problems arising in commetted with underground excavations, has a definite effect on the work of the military geologist. It becomes especially complicated in underground excavations undervaken in the immediate proximity of the enemy, when offensive mine galleries must be laid under enemy-held territory.

The military geologist and mine expert are compelled at times to be satisfied with only meager observations, not always conducted at points most helpful for the clarification of the geological situation. Sometimes they are necessarily restricted to geological materials on hand in the form of military-geological maps, handbooks, etc.

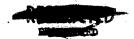
Enveror, despite the fact that the military situation in most cases hinders execution of field geological observation, it is nevertheless necessary for successful execution of underground mine operations to get accurate data.

As a rule, it is not possible to secure adequate geological data on the forward edge before the beginning of underground mine works. Therefore, geological observation must be carried on throughout the course of work. The data gathered as a result of these observations paralle correction of the geological situation assumed in the operational plan of mine works. Observations conducted throughout the entire period of underground mine excevations are especially necessary in view of the fact that practical problems are constantly maining in connecting with the various phases of underground mine work, such as bracket, prevention of deformations of the strate, revoval of vator, organization of listening posts, calculation of the size of explosive charges, relation of the gas conductivity of the strate, etc.

Details of the gaulogical situation can only be obtained after uncovering the strate.

In manuals on underground mine work and mine vertere appropriate





attention is given to military geological reconnaissance.

The manual on underground mine works for engineers states "The composition and character of the occurrence of soils, the height of the water table for every underground construction must be determined by geological-engineering recommissance.

"The aim of geological-engineering recommaissance is to establish the conditions for the construction of underground installations and the waging of mine warfare in a place selected by tactical decision. It is carried out by:

"(1) Study of geological maps, hamibooks, and local materials; (2) recommaissance with prescribed itinstary in which geological information is
gathered through observation of the relief, the run-off of surface waters,
[water] sources and outcroppings; (3) drilling with the aim of mapping the
geological profile of the area along the axis of the proposed construction."

These rules of the manual require further supplementation, as follows:

- 1. It is not practically possible in every case to undertake time-consuming prospecting, requiring specialized equipment.
- 2. Nost often the geological situation must be appraised on the basis of previously gathered material, in the form of maps, handbooks, etc. Specialized military-geological maps play as important a role in underground mine works as topographical maps play in the planning of operations for tank warfare.
- Decisions on the tactical combuct of mine warfare should precede the study of maps, cross sections and other available material dealing with geology.

As a rule, geological maps, cross sections and various other tabulated information are available for almost every territory in which underground operations can be conducted. In most cases, however, the data is scattered and requires preliminary processing.

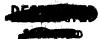
Often one is forced to use small-scale geological maps when more detailed geological maps are not available.

Large scale geological maps (scale 1:10,000 and 1:25,000), as is known, are to be found for mamorous areas of Western Europe. For Eastern Europe maps of this type are restricted to densely populated and highly industrialized areas. Specialized large-scale maps for underground mine works are drawn beforehand for regions determined by the command or after the commencement of military operations.

Maps must always be accompanied by profiles 'cross sections' in various directions and primarily in the direction of the intended course of the galleries.

Often recurse is hid to the construction of more descriptive block diagrams and disconsistic cross sections. Likewise, specialized, military-geological cross-section belown are of value in underground mine works (Figure 39).

However, maps and cross sections alone often prove insufficient for the solution of practical problems which arise in underground wine variare, and supplementary military-quological investigation in the form of surveying and recommissance are required. In manuals of underground wine works prescribed itinsway and drilling recommissance are manifested.



A recombissance party is besided by the commander of a combat-engineer battalion, or by the experienced commander of a combat-engineer company, less often by the commander of a combat-engineer platoca. If the geology of the area is simple, if the commissance group has sufficient experience in geological observation, the information gathered may prove to be adequate for the solution of all practical problems. However, if the geology of the area is complicated, if combat conditions binder carrying out the necessary cheervations, if the commander of the engineering unit does not have adequate geological training or the measury experience which yould allow him to make the requisite generalizations from a limited number of facts, then such recommissance will not only fail to be described but may prove hereful. In such a case recommes is had to the aid of military geologists, who know the peculiarities of field underground operations.

The military geologist's aid to the command varies greatly in character. In some cases this aid may be limited only to supplying geological information which is used as the basis of operational and tactical plans of mine works. In other cases the military geologist undertakes military-geological recommands and the necessary observations while anderground work is going on. These geological and hydrogeological observations connected with underground excavations have great practical value.

The military geologist can render great aid to the command by determining the position of the enemy. Information concerning what lovels the enemy is working or is able to work in and that difficulties he may encounter must be communicated by the military geologist to the commander immediately. Asriel-photographic materials, captured documents, and the interrogation of prisoners should assist him in securing the necessary information.

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